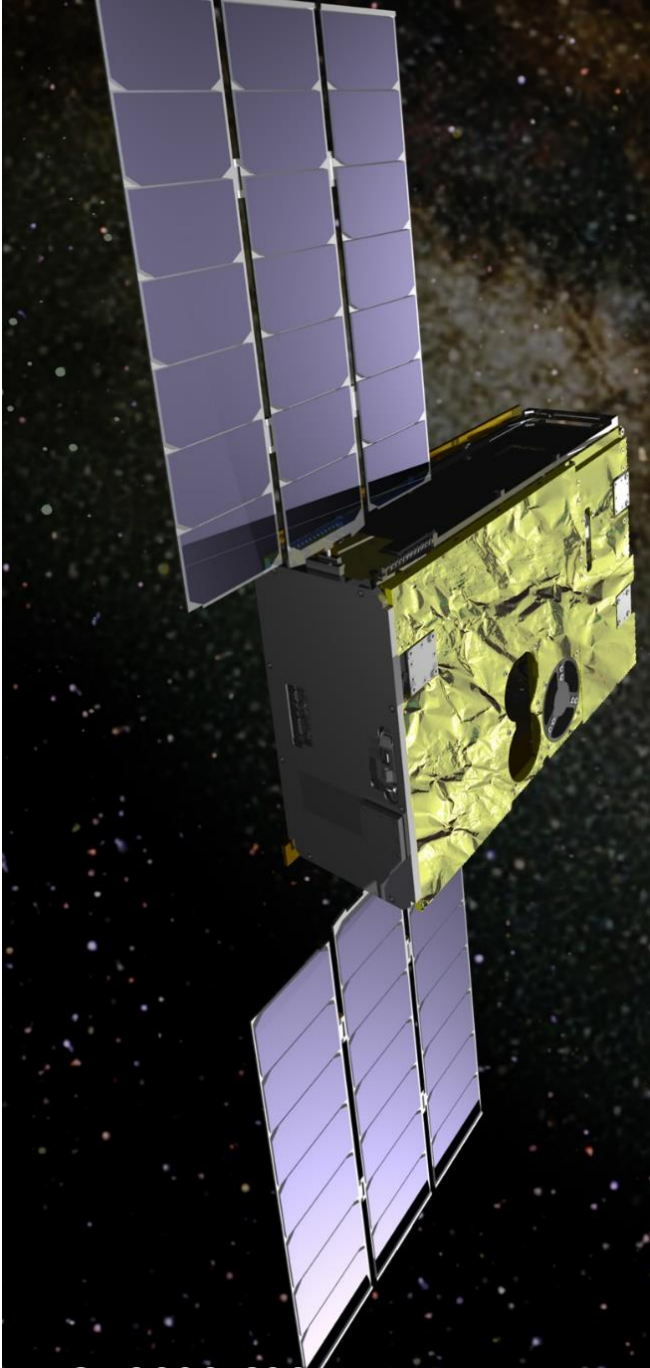

2021 L.O.

EUV observation for Earth's plasmasphere from EML2 by nano-spacecraft

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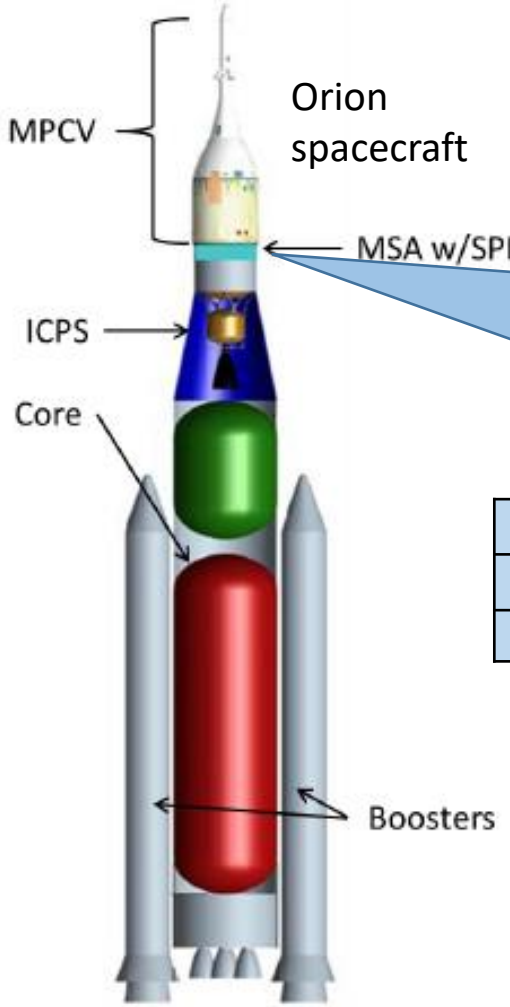
1: The Univ. of Tokyo, 2: ISAS/JAXA

EGU2020-6204

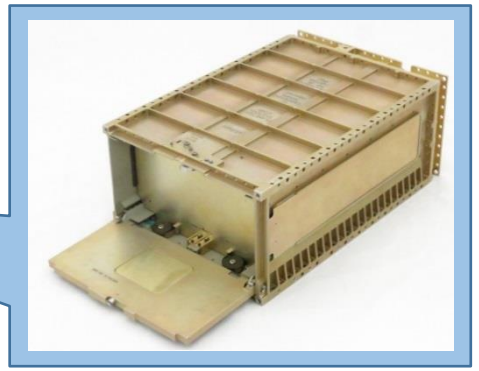
EQUULEUS will be launched by SLS

- EQUULEUS is one of the CubeSat boarded on the SLS#1.
- SLS#1 will be launched in 2020.

- 3 science instruments
  - **PHOENIX**
    - EUV telescope for Earth's plasmasphere
  - DELPHENUS
    - Impact flash camera for Moon surface
  - CLOTH
    - Dust monitor (MLI)



SLS (Space launch system)



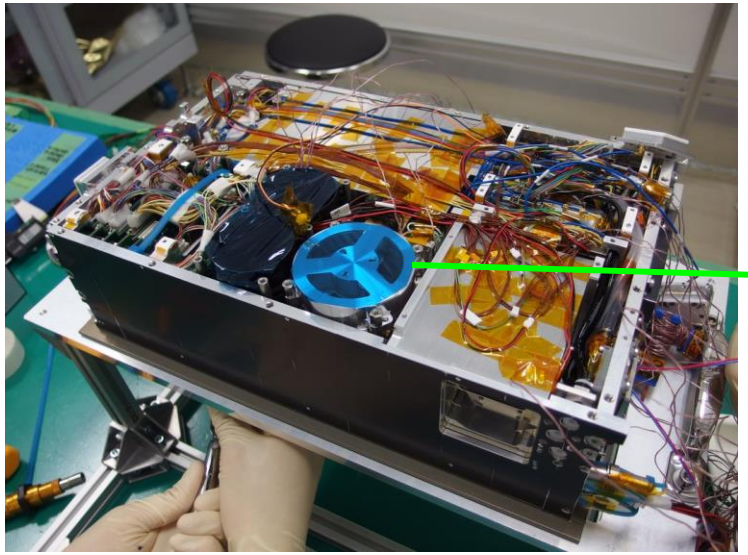
CubeSat (6U)

×13

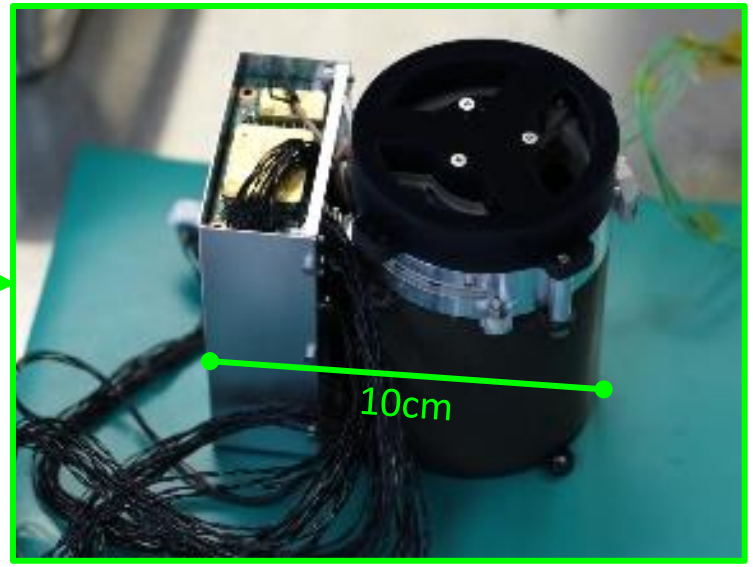
Max. Dimension (X direction)	239 mm
Max. Dimension (Z direction)	366 mm
Max. Dimension (Y direction)	113 mm

PHOENIX on EQUULEUS (6U, 14kg sc)

- **EQUULEUS** will be launched in 2021 by NASA's SLS.
- **PHOENIX** is an EUV (30.4nm) telescope for He^+ emission in Earth's plasmasphere.
- **EML2 is suitable for continuous monitoring** of the plasmasphere from equatorial plane.



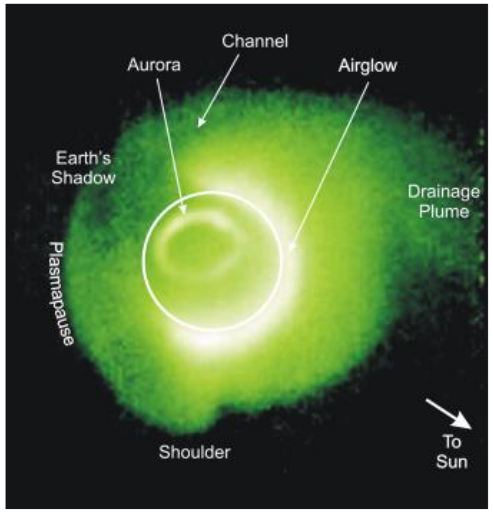
EQUULEUS



FM of PHOENIX with FPGA

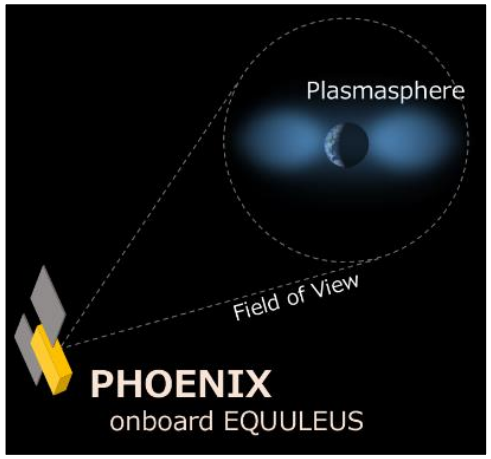
PHOENIX telescope (Science objective)

- Plasmasphere
  - Earth is surrounded by plasmas
    - H^+, He^+, and etc.
  - He^+ can be observed remotely by emission line
    - Wavelength at 30.4 nm.
- Observation geometry
  - By flying far from the Earth, the entire **image of He^+ distribution** can be obtained.
  - The image **from the equatorial plane** help understanding the dynamics of plasmas along the magnetic field.



Top view

He^+ emission (30.4nm) seen from the north pole direction (NASA/IMAGE mission).

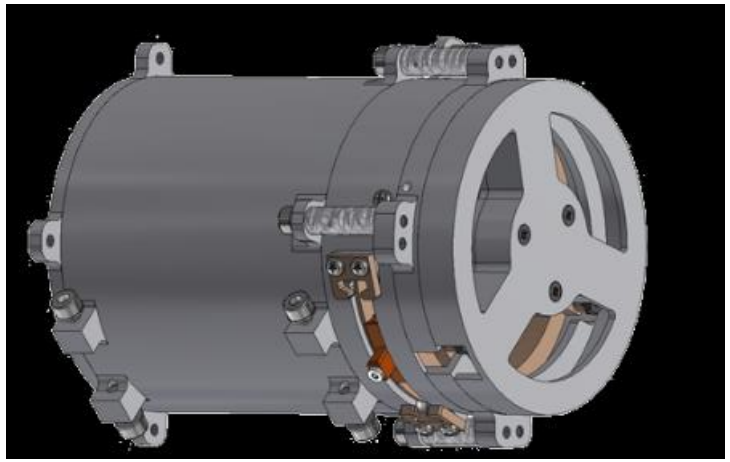


Side view

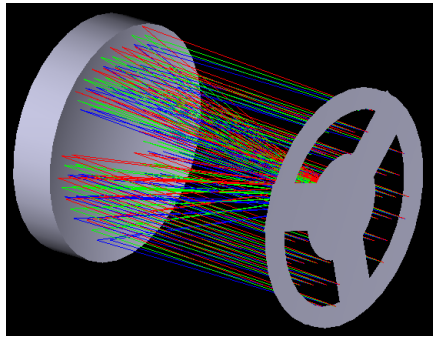
Entire image of He^+ from the equatorial plane can be obtained by PHOENIX.

PHOENIX: 0.5kg EUV telescope

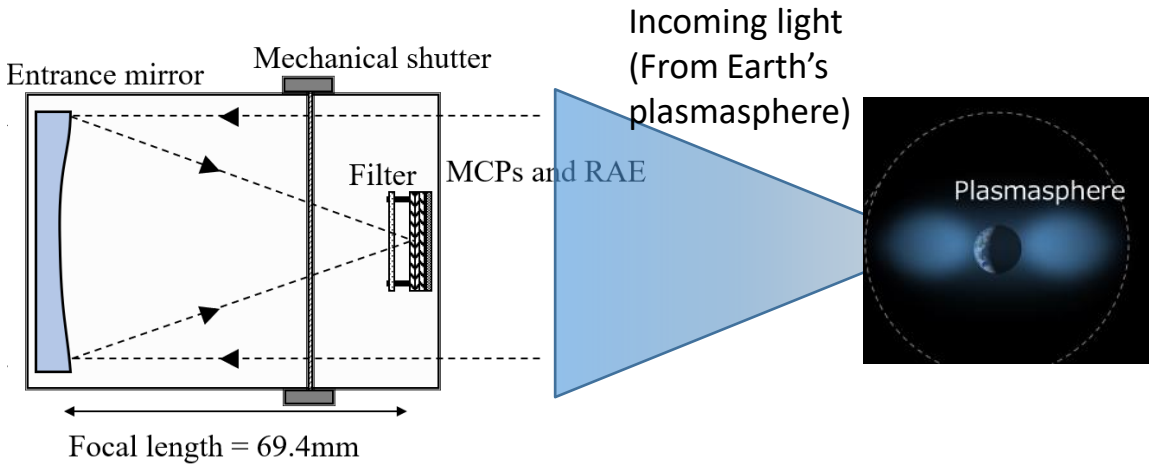
- A mirror and detector are optimized for He^+ emission line 30.4nm.
- Only one reflection by a spherical mirror (not parabolic).



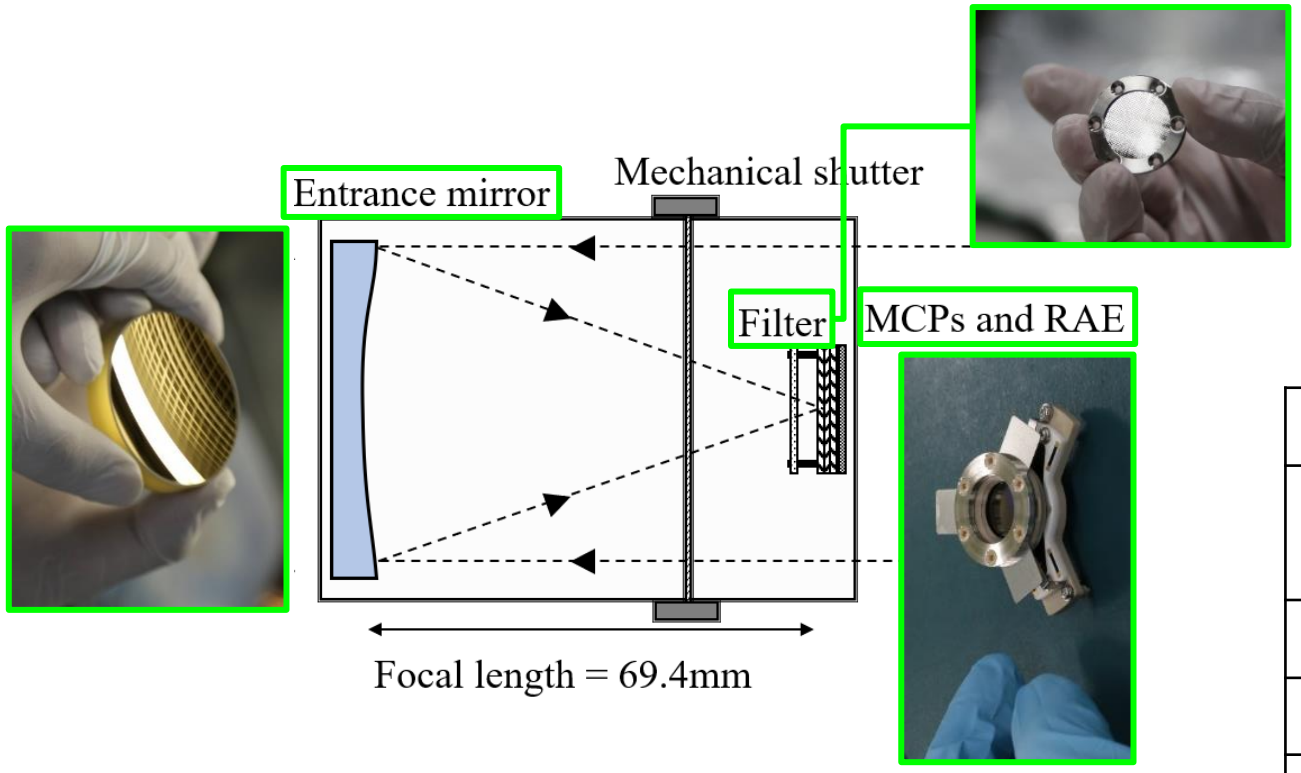
PHOENIX mechanical design



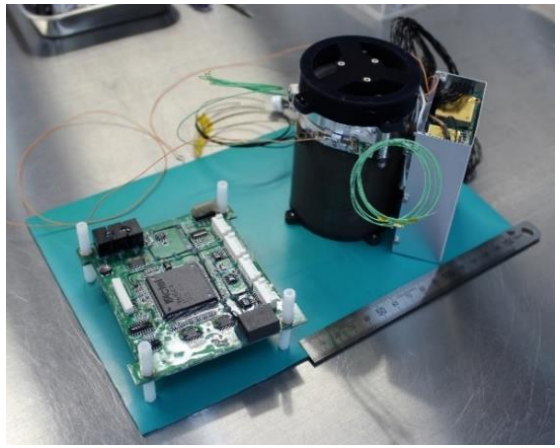
Optical design of PHOENIX



PHOENIX: 0.5kg EUV telescope



Optical design of PHOENIX

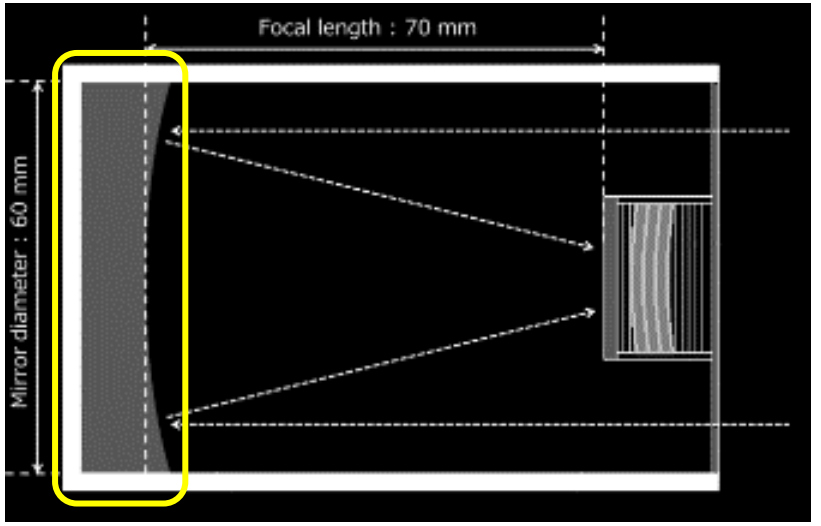


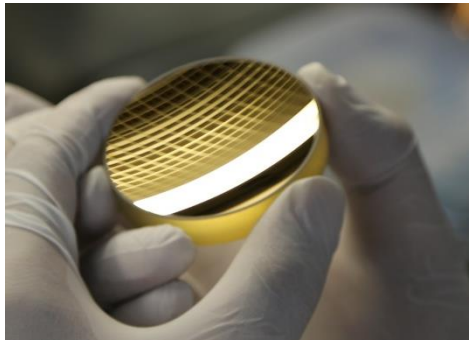
FM of PHOENIX with FPGA

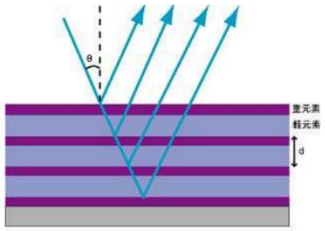
Mass (FM, measured)	537.7g (with cables)
Power (FM, measured)	1.5~1.8W (during observation) *Temperature dependent
Size (outer envelope)	6.6 cm x 6.6 cm x 10cm
Field of view	8deg. x 8deg. ($8R_E$x$8R_E$)
Spatial resolution	< 0.1 deg. ($0.1R_E$)
Temporal resolution	10~60 minutes.

Wavelength selection (Mirror)

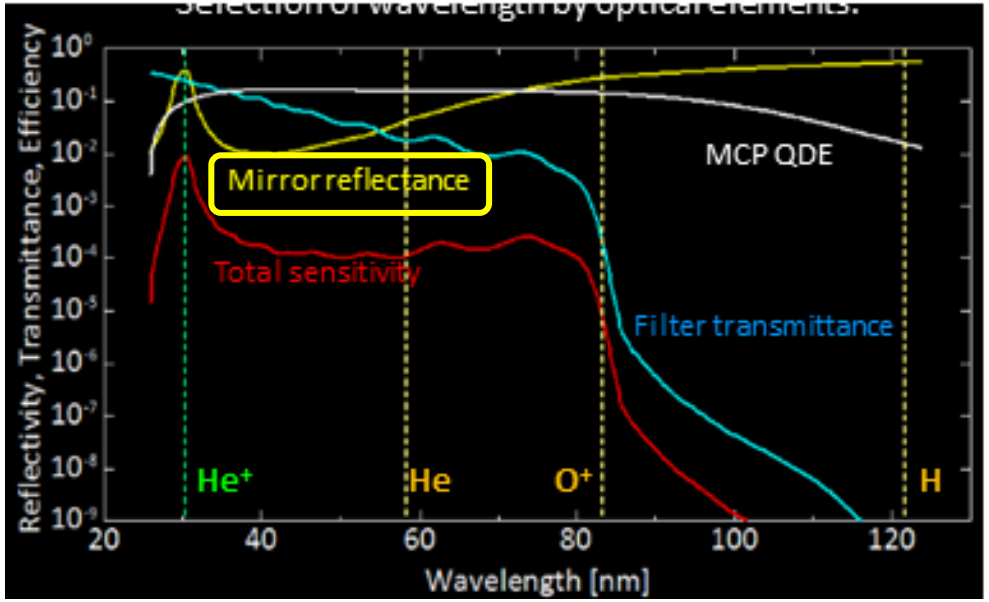
- Elimination of lights from another sources.
  - **HI 121.6nm: > x10^4**
  - **OI 83.4nm: > x10^2**
  - **HeI 58.4nm: > x10**
- Wavelength is selection by…
  - **<u>Multilayer mirror</u>**
  - Metallic thin filter
  - Photon detector





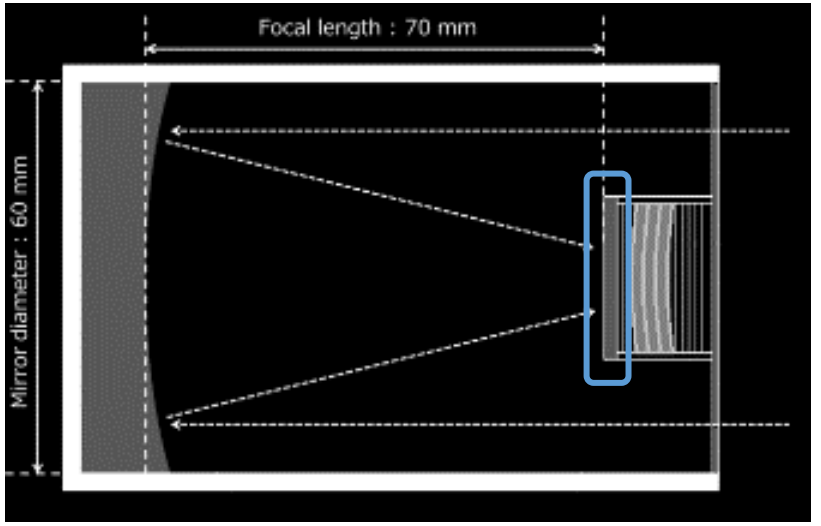


Multilayer of Mg/SiC

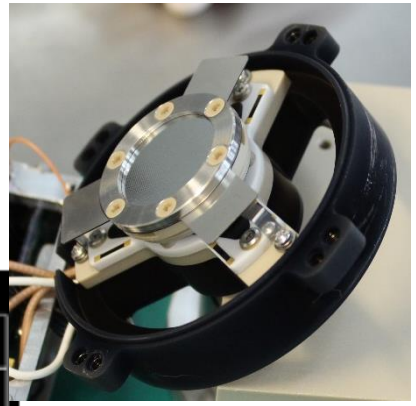


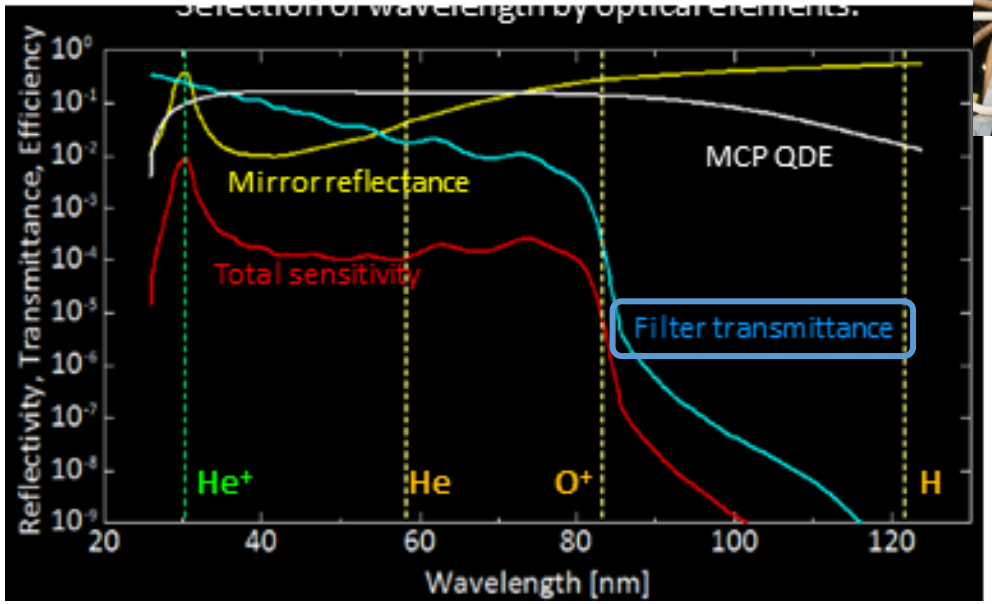
Wavelength selection (Metallic thin filter)

- Elimination of lights from another sources.
  - **HI 121.6nm: > x10^4**
  - **OI 83.4nm: > x10^2**
  - **HeI 58.4nm: > x10**
- Wavelength is selection by…
  - Multilayer mirror
  - **<u>Metallic thin filter</u>**
  - Photon detector



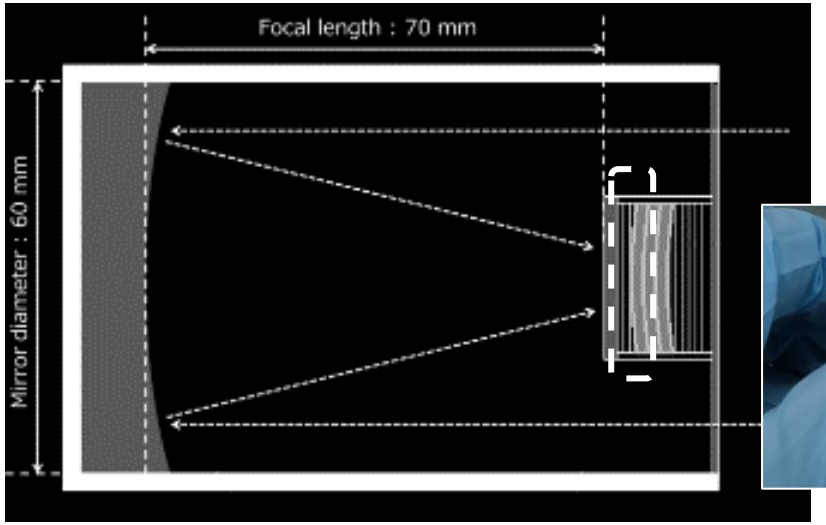
Metallic thin filter (C/Al/C)



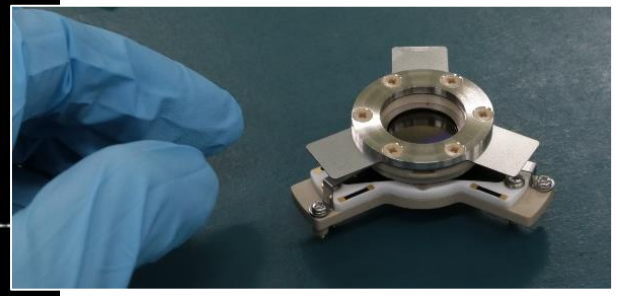


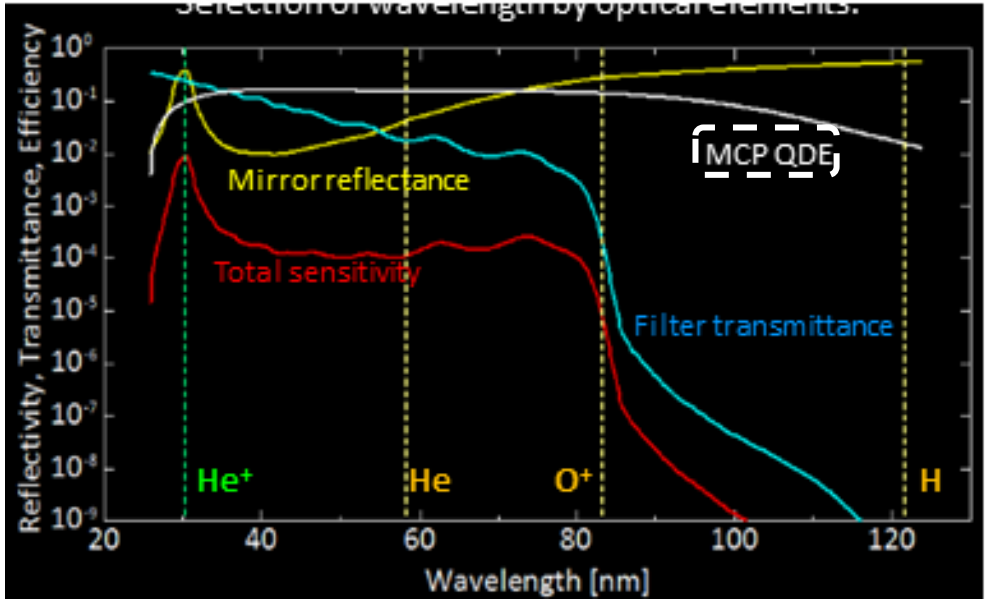
Wavelength selection (Photon detector)

- Elimination of lights from another sources.
  - **HI 121.6nm: > x10^4**
  - **OI 83.4nm: > x10^2**
  - **HeI 58.4nm: > x10**
- Wavelength is selection by…
  - Multilayer mirror
  - Metallic thin filter
  - **<u>Photon detector</u>**



Photon detector (MCP)

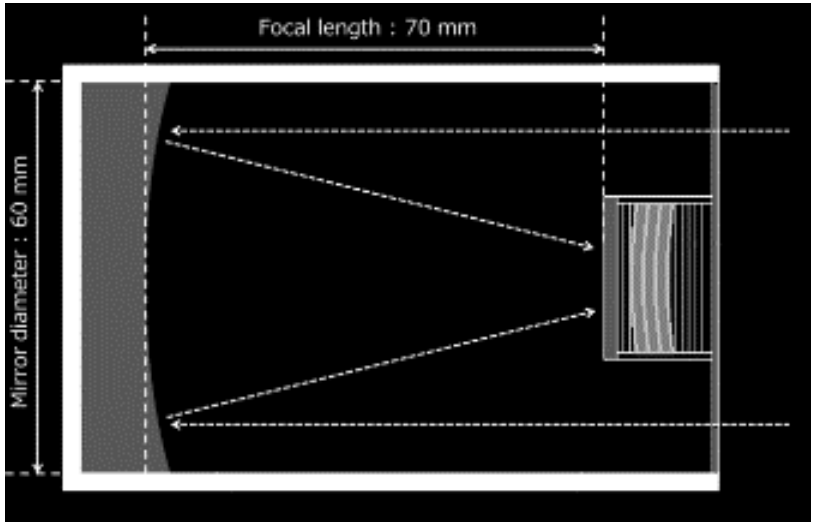




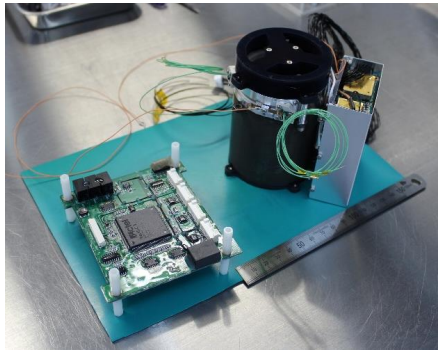
Wavelength selection (Overall)

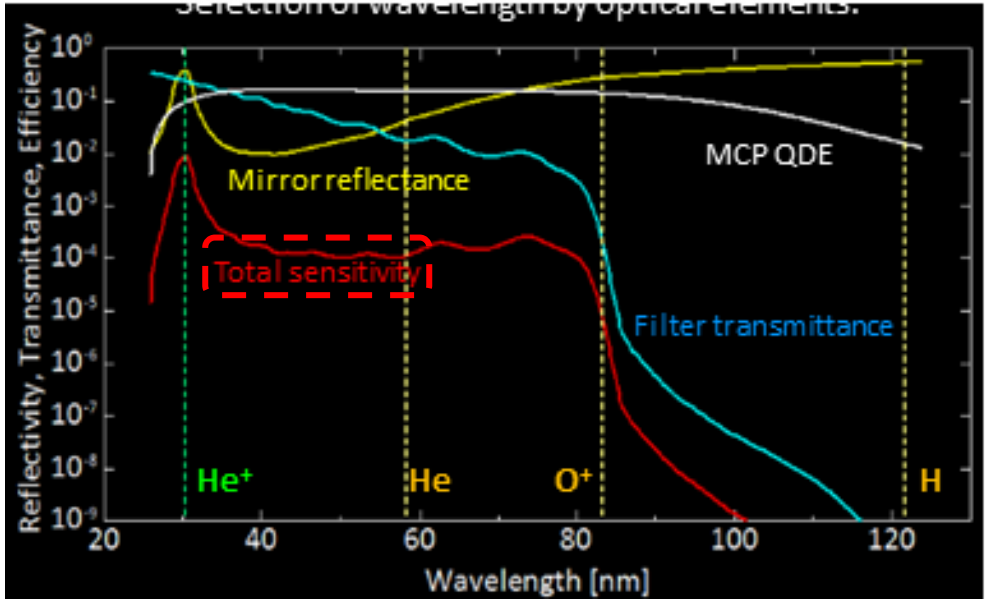
- Elimination of lights from another sources.
  - **HI 121.6nm: > x10^4**
  - **OI 83.4nm: > x10^2**
  - **HeI 58.4nm: > x10**
- Wavelength is selection by…
  - Multilayer mirror
  - Metallic thin filter
  - Photon detector

Optimized for 30.4nm

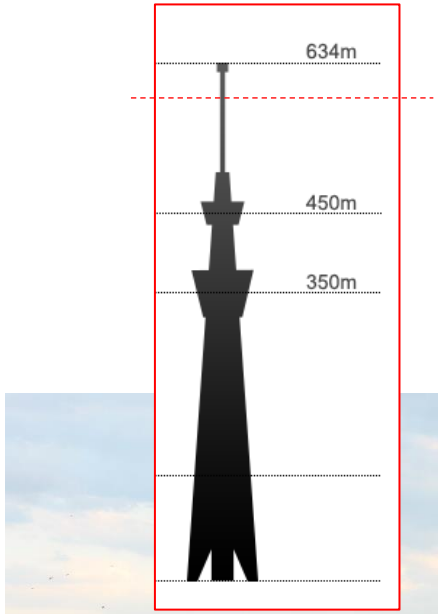


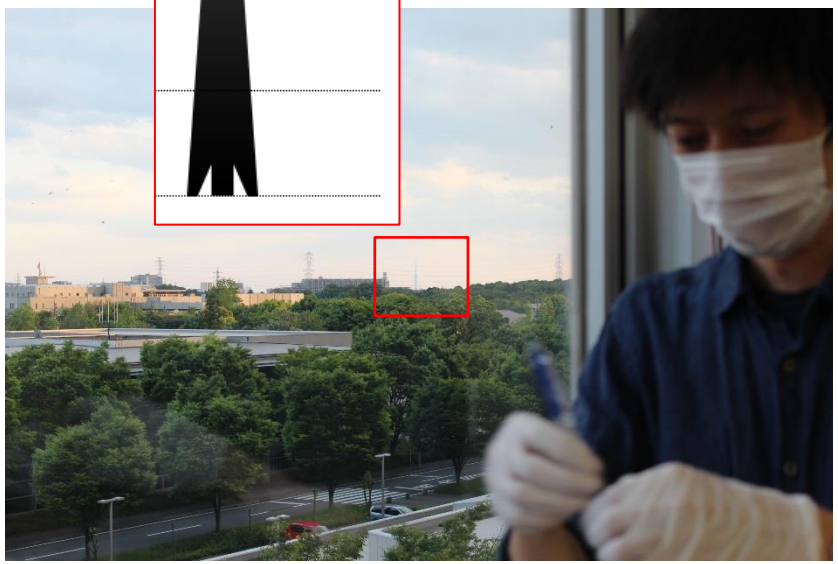
PHOENIX FM (with elec.)



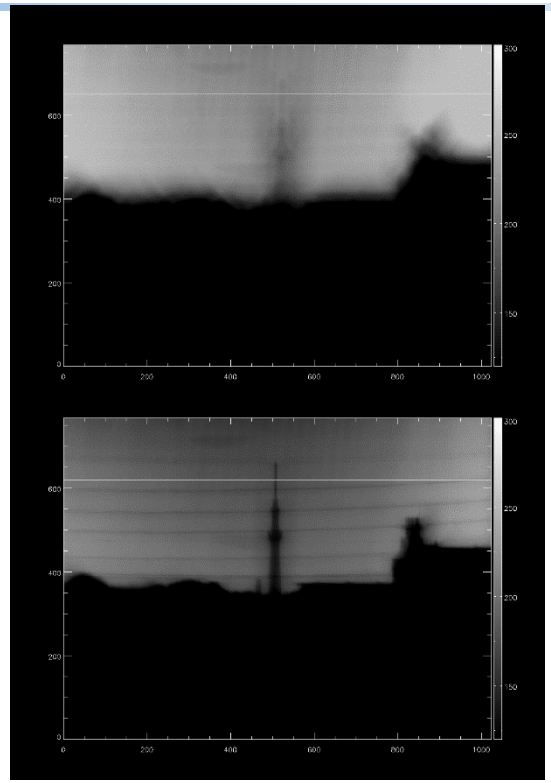


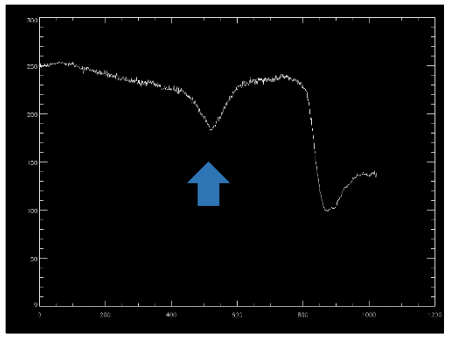
Optical performance (FM)

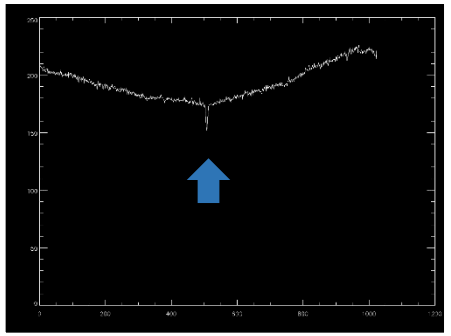




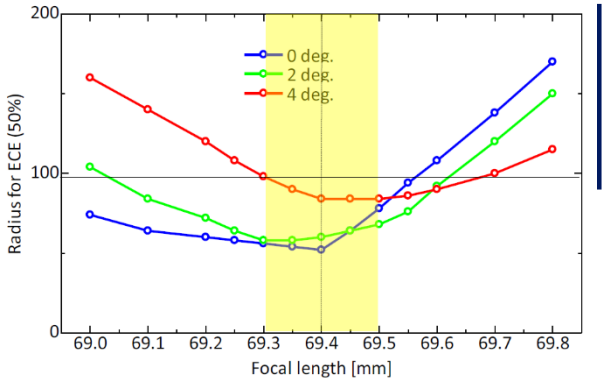
Sky-tree from UT Kashiwa campus
Distance from Kashiwa to Sky-tree: 24km



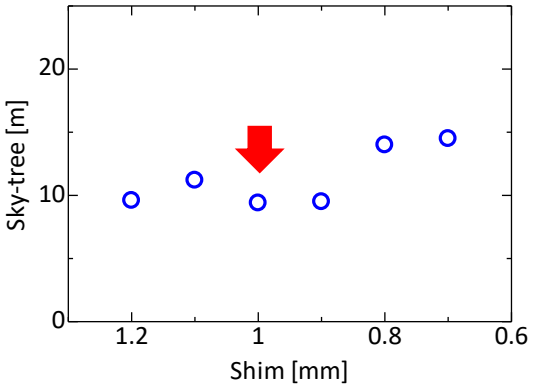




Shim (0.5~1.2mm)



Defocus analysis (calc.)

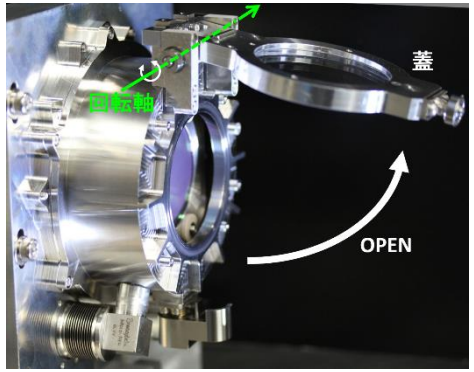


Shim vs width (meas.)

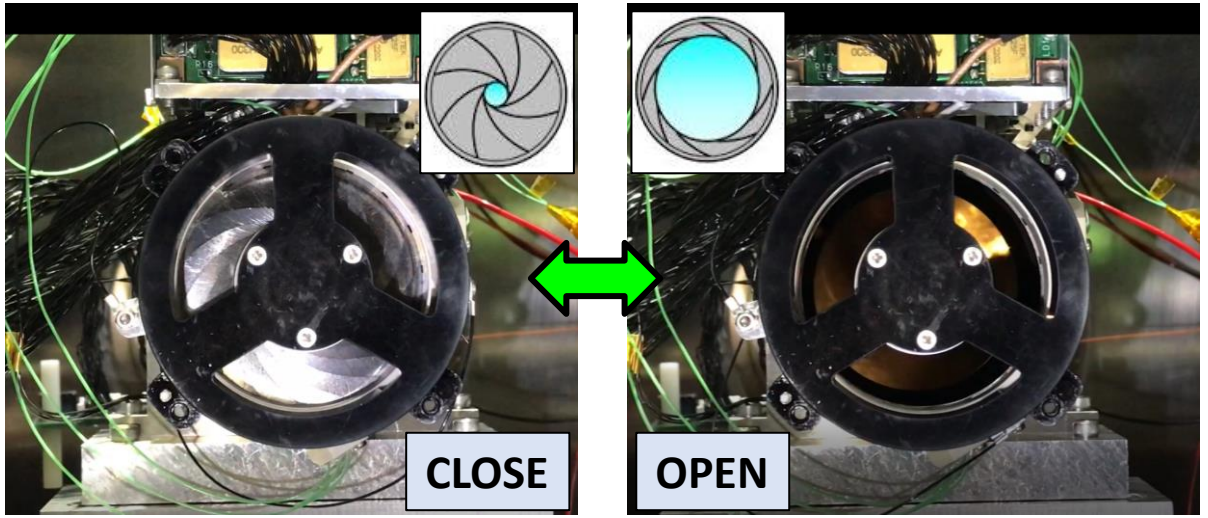
0.1 R_E from moon: ~0.1 deg.
Sky-tree width viewed from Kashiwa: ~0.023 deg.

Shutter system for PHOENIX

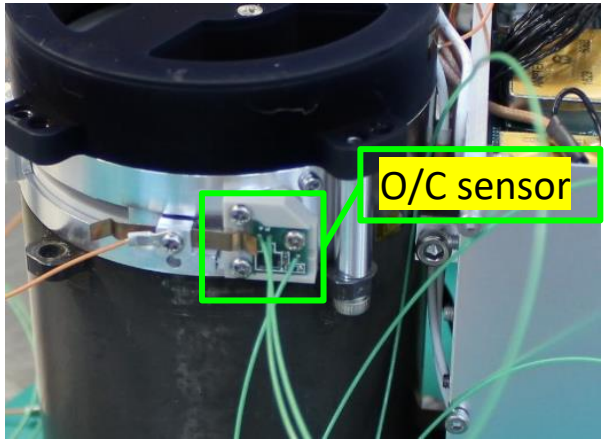
- Shutter system is needed to avoid…
  - Pollution for the mirror, filter, and detector during the ground operations.
  - Incoming solar light during the flight. (Everything is fully damaged!!)
- Former missions (BepiColombo, ISS/IMAP, Hisaki/EXCEED) adopted the 1-axis door open/close system.
- However… No space for such system in nano-spacecraft missions.



Bepi/MPO/PHEBUS



FM shutter in vacuum



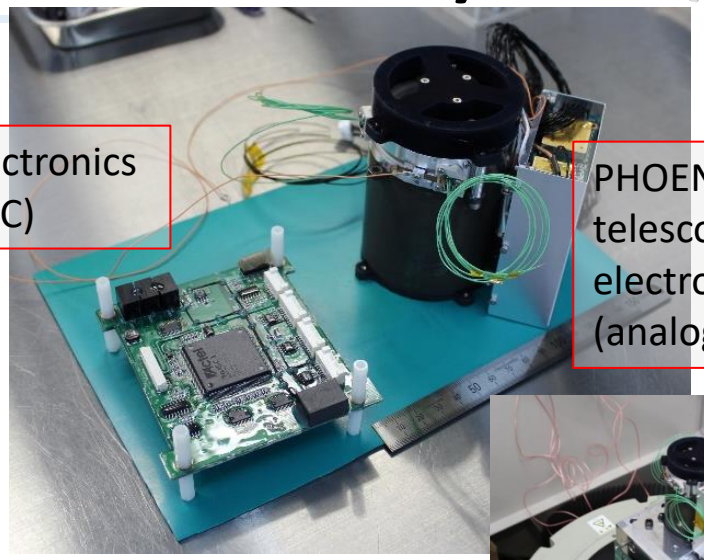
Sensor system

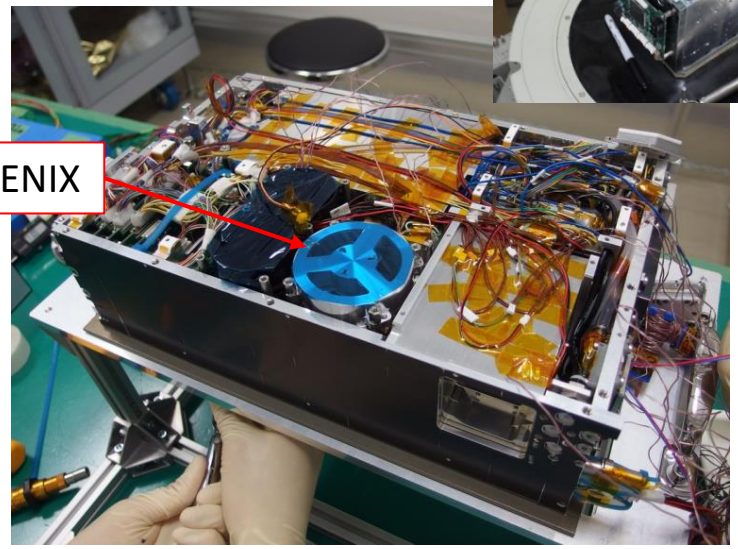
Summary and conclusion

- PHOENIX telescope (on board nano-spacecraft, EQUULEUS) will observe Earth's plasmasphere by using He+ emission.
- The side view image of the He+ plasmasphere (from Earth-Moon L2 point) will tell us the plasma dynamics (especially) along the magnetic field.
- We are trying to develop the key techniques for nano-spacecraft.
  - Small photon detector and electronics.
  - Shutter system (with bio-metal fiber springs).
- FM (PHOENIX and EQUULEUS) is now under the construction.

Development status of PHOENIX (and EQUULEUS)

- System Kick off meeting [2016.6.16]
- Mission PDR (Preliminary Design Review) [2016.8.25]
- System EM thermal vacuum test [2017.5.20]
  - PHONEIX electronics works (some modification is needed)
- System EM Shock and Vibration test [2017 June]
- PHOENIX FM integration on EQUULEUS [2019 Oct.~]
- System environment test for FM [2019 Dec.~]
- Launch (by SLS) [2021 TBD]





EQUULEUS (EM)